

Plant Optimization Strategy for Nitrogen Removal Town of Crewe Wastewater Treatment Facility

Introduction:

Recent regulatory changes in Virginia will require the majority of wastewater treatment facilities to significantly reduce the discharge of nitrogen and phosphorus in the final effluent discharge. While most facilities will require an expansive upgrade to comply with the new requirements, the Town of Crewe operating staff have been evaluating the existing treatment facility for increased reductions of nitrogen and phosphorus through operational modifications.

Although the facility relies upon chemical precipitation to remove phosphorus, plant staff have made adjustments to several treatment process parameters in an attempt to reduce total nitrogen levels from the existing plant.

Background:



The Town of Crewe is located in Nottoway County, Virginia about 60 miles Southwest from, the state capital, Richmond. With an estimated population of 2,386 and a total land area of 2.0 square miles (5.3 square kilometers), this modest community is known for its connection to the Norfolk and Western railroad company, having taken its current name from an old railroad town in Eastern Europe.

The Towns' wastewater treatment system consists of 8 wastewater pumping stations, 11 miles of underground piping and 1 centralized wastewater treatment facility. The treatment facility was originally constructed in 1956 as a trickling filter treatment process and was upgraded to a 0.500 MGD activated sludge, oxidation ditch facility in 1997. The design included the following treatment processes:

Liquid treatment:

- Preliminary (screening and grit removal)
- Biological (3 channel Orbal® process)
- Sedimentation (2 secondary clarifiers)
- Phosphorus removal (alum addition)
- Disinfection (Cl_2/SO_2 gas)
- Post aeration (cascade steps)

Solids treatment:

- Aerobic digestion
- Dewatering (Belt filter press)
- Landfill disposal



Although the facility was not designed for total nitrogen removal, an oxidation ditch process does offer several operational control options to improve upon the plants current nutrient removal performance.

Nutrient removal performance:

Beginning January 1, 2007 the facility began operating under the General Permit for Total Nitrogen and Total Phosphorus Discharges and Nutrient Trading in the Chesapeake Bay Watershed (9-VAC- 25-82-70). Under the general permit, the Crewe wastewater treatment facility has an annual waste load allocation (WLA) of 9,137 pounds for total nitrogen (TN) and 761 pounds for total phosphorus (TP). At design flow this WLA equals a TN concentration of 6.0 mg/L and TP 0.5 mg/L, respectively. Reported nutrient data for 2005 and 2006 is summarized in Table 1 below.

Table 1 Nutrient Data 2005 & 2006

Reported Nutrient Data 2005		Reported Nutrient Data 2006	
Flow (MGD)	0.27	Flow (MGD)	0.26
TN Average (mg/L)	7.11	TN Average (mg/L)	8.59
TP Average (mg/L)	0.53	TP Average (mg/L)	0.31
TN (Pounds/year)	5,689	TN (Pounds/year)	6,790
TP (Pounds/year)	427	TP (Pounds/year)	209
TN (Excess capacity)	3,448	TN (Excess capacity)	2,347
TP (Excess capacity)	334	TP (Excess capacity)	552

Source: Town of Crewe Operating Data

Optimization efforts:

Plant operating staff have put in a tremendous amount of effort to improve upon the plants current nutrient removal performance and so far the results have been promising. The following actions were taken to optimize the current facility for nitrogen removal:

- Alkalinity

The nitrification process uses 7.14 pounds of alkalinity/pound of ammonia converted to nitrate. Without sufficient alkalinity, process performance will decrease. Facility staff are adding approximately one hundred (100) pounds of lime to the 1st channel of the oxidation ditch daily, at an approximate cost of \$24.00 per day, to maintain enough alkalinity for nitrification.

- Carbon Source

The denitrification process utilizes heterotrophic bacteria to convert nitrate nitrogen to nitrogen gas. These organisms must have a readily available carbon source to effectively support their life functions. Typically, in a pre-anoxic mode of denitrification, influent carbon (BOD) is used to supply this food source. Additional BOD can be used to increase the performance of this process. The town of Crewe is currently adding approximately one hundred fifty (150) lbs. of dried molasses daily, at an estimated cost of \$33.00 per day, to the 1st channel of the ditch to provide an additional carbon source for denitrification.



- Dissolved Oxygen Control



Improved control of the aeration rates can enhance nitrification/denitrification performance by providing a controlled aerobic/anoxic environment. Typically, in an oxidation ditch process, D.O. levels are kept at less than 0.5 mg/L in the outer channel and between 1.0 – 3.0 mg/L in the inner channel(s). At the Town of Crewe WWTP, whenever D.O. levels in the oxidation ditch were lowered to attempt to improve denitrification, an increase in total kjeldahl nitrogen (TKN) occurred. Beginning in January 2007, plant operating staff decided to develop an effective yet low cost alternative

to controlling the D.O. level in each channel of the ditch to improve denitrification while maintaining effective TKN reduction.

One method of controlling D.O., in an oxidation ditch with disc aeration, is to remove/add aeration discs in each respective channel. Plant staff considered this method but were concerned that the mixing velocity might be affected, causing settling in the ditch. Plant staff decided to experiment with operating the ditch aerators in an on/off operation mode. A 24hr. timer with 15 minute on/off cycles was used as an initial test to determine its effectiveness in maintaining the D.O. at the desired levels. The timer was wired to one of the two available aeration motors. The timer cycled on/off effectively, but was not capable of altering the speed of the motor. The plant achieved marginal success with this modification.

The second test was initiated using the same timer, on one side, to alter the speed of the motor in cycles. This was accomplished by having the timer set-up with “normal” operation as operating the aerators in high mode. When the timer triggered a cycle, it changed the speed from high to low for the preset duration, returning to high mode upon completion of the cycle. Delay timers were employed to stop and start the motors, limiting the impact this may have on the equipment.



A D.O. probe monitors the D.O. concentration of the mixed liquor and sends a corresponding signal to a controller device. The controller device is used to adjust the disc aerators to high or low speed by opening / closing relays in response to pre-determined set-points.

Through trial and error, it was discovered that the most effective place for the D.O. probe was in the third channel. Experience had shown

that when D.O. levels fell below 3.0 mg/L in the third channel, a significant increase in TKN levels occurred. Although the corresponding D.O. in the first channel was low enough to increase denitrification and thus further reduce nitrates, the increase in TKN resulted in no substantial change in total nitrogen levels (TKN + nitrite + nitrate = total nitrogen). After further experimentation, it was discovered that a set-point range between 3.6 - 4.0 mg/L offered a more balanced approach to controlling both total nitrogen and TKN levels.

This operational method has provided the plant a measure of control beyond the “on/off” approach to limiting D.O. levels within the ditch. The method provides a simplistic approach to the need for constant adjustment to balance both the TN reduction and TKN reduction processes. It provides “D.O. control”, which is a vital component of a plants nutrient reduction strategy. Total costs for the system were approximately \$6,000.00; however, it should be noted that the facility staff designed and installed the system themselves, which resulted in a significant cost savings to the town.



- Sampling and Testing



Increased process monitoring has been helpful in determining plant performance and establishing appropriate control levels. Facility staff are performing additional process control sampling and testing to characterize and monitor the treatment process. Nitrogen profiles have been used to determine where adjustments are needed and if these adjustments have been effective in increasing nutrient removal performance. Samples are analyzed in-house and by an outside source. A good working relationship with an outside laboratory has proven to be essential in the Town's efforts to

reduce nutrients. They are able to verify in-house results in a timely fashion and adjust the process based on these results.

Possible limiting factors:

There were several other operating factors that are currently being addressed to potentially increase the efficiency of TN removal.

- Inflow/Infiltration (I/I)

The Town has dealt with significant I/I problems which may have directly impacted the performance of the system to achieve optimal nutrient removal. The Town is currently working diligently to improve the I/I issues and increase the pumping capacity and storage ability of the plant. The town has completed slip lining several problem areas within the collection system. These corrections have resulted in an immediate decrease in the amount of inflow and infiltration flow received at the plant during a rain event.

- Internal recycle



Typically, facilities operating for nitrogen removal use an internal recycle to return a much greater quantity (2 - 4 Q) of flow, rich in nitrate nitrogen, back to the anoxic zone for conversion to nitrogen gas. The current plant configuration does not include an internal recycle, but the facility is performing a pilot test on using a temporary internal recycle system, using a submersible pump and PVC piping, to determine the effectiveness in further reducing nitrogen levels. This pump recycles nitrates from the 3rd channel (aerobic) back to the 1st channel (anoxic) at

approximately 130 GPM. Plant staff have determined a 1:1 ratio works best to maximize nitrate removal.

- Oxygen addition (anoxic channel)



Excessive agitation occurred where the influent and RAS enter into the anoxic zone (1st channel) of the oxidation ditch. D.O. measurements indicated a D.O. of 0.4 mg/L before and 0.8 mg/L after the influent discharge and 1.4 mg/L after the RAS discharge. This dissolved oxygen must be used up by biological activity before denitrification will occur.

In an attempt to decrease the D.O. at this location, the operating staff extended both the influent and RAS piping below the water surface in the 1st ditch. Results have been immediate, decreasing the D.O. by as much as 1.0 mg/L where the influent and RAS enter the ditch.

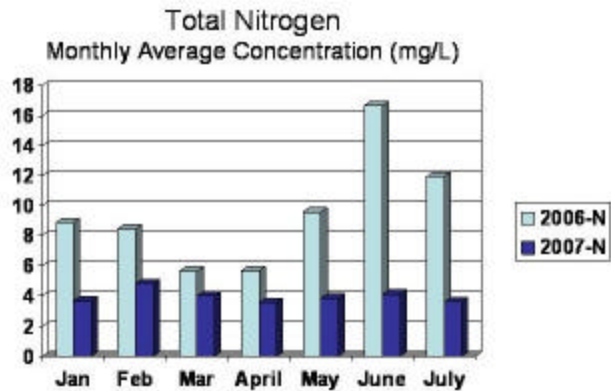
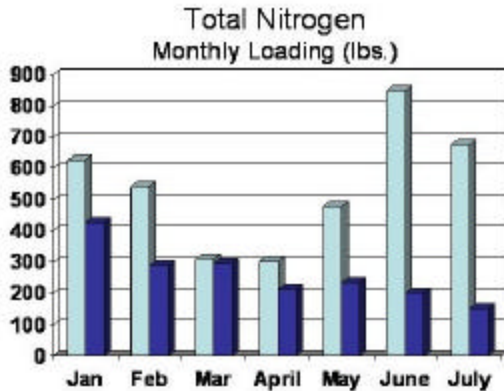
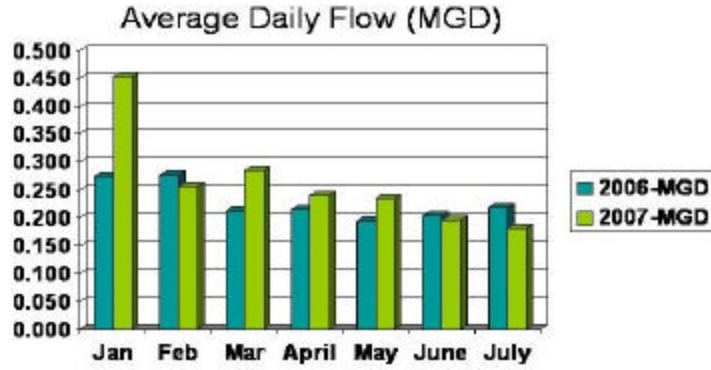


- Sidestream flows

An often overlooked contributor of nutrients in plant influent is a result of internal plant processes. If not managed properly, these sidestream flows can significantly affect the plants ability to consistently remove nitrogen and phosphorus. The operating staff observed that whenever they decanted their aerobic digester and/or operated the belt filter press an increase in plant influent nitrate levels occurred. Currently, the aerobic digester is being operated in an "on/off" mode (2 hrs. on/1 hr. off) to reduce the nitrates before they enter the plant influent. This operational mode has resulted in an increase in ammonia/TKN levels but the process seems to be handling this load effectively. Plant staff are continuing to monitor the nutrient levels to determine if any adjustment to the operational strategy is required.

Optimization results:

As a result of the adjustments made by the plant operating staff, the total nitrogen discharged by the facility has been reduced, on average, by greater than 50%. A series of bar charts comparing 2006 and 2007 total nitrogen and flow data has been provided below.



Plant staff are continuing to determine the impact the operational changes have made on total nitrogen levels in anticipation of weather changes and variations in influent characteristics.

For more information regarding plant operations and/or nutrient removal performance, contact John Hricko, plant manager @ (434)-645-9436 or email: hricko@hovac.com

Town of Crewe WWTP Flow Scheme



1	Bar Screen
2	Grit Removal
3	Pump Station
4	Oxi-Ditch a = #1, b = #2, c = #3
5	Alum Feed Location
6	Splitter
7	Sec. #1
8	Sec. #2
9	Cl ₂ C.T.
10	Cascade Steps
11	Chemical Feed Building
12	Sludge Pump Station
13	Aerobic Digestion
14	Belt Filter Press

